

SCOMM

77:35

APR-12-91 FRI 13:27 BLED SOE & KNUTSON
JAMESON & CLARAVAL
Attorneys at Law

P. 01

125, 126-130 Laurel Street
P.O. Box 11833
Harrisburg, Pennsylvania 17108-1833

2525 Blueberry Road, Suite 208
Anchorage, Alaska 99503
Telephone (907) 272-5200
Facsimile (907) 279-2321

530 Second Street
P.O. Box 1828
Cordova, Alaska 99575

Telephone (717) 236-7888
Facsimile (717) 232-8808

Telephone (907) 424-7410
Facsimile (907) 424-7434

FACSIMILE COVER SHEET

To: DATE: 4/12/91
FILE NO: 1266
465-4565 → Mary McDonnell
Max Gruenberg Dick Eliason 465 4928
TO: _____
COMPANY: _____
PHONE NUMBER: _____ FACSIMILE NUMBER: _____
RE: Exxon Settlement
FROM: Jeff Parker
NUMBER OF PAGES (INCLUDING COVER SHEET): 15
COMMENTS: See p. 3 - I would strongly urge
you to get the testimony of the economists named
on p 3 who performed the damage calculation
studies and were to be expert witnesses for
OPERATOR: JP the State and the
United States. I

believe the names of these experts
have not been made public until
now and the Legislature and Congress
IF YOU DO NOT RECEIVE ALL OF THE ABOVE STATED PAGES,
PLEASE CALL (907) 272-5200 IMMEDIATELY.

deserves to hear from them.

Jeff

ADLER, JAMESON & CLARAVAL

Attorneys at Law

125, 125-130 Locust Street
P.O. Box 11933
Harrisburg, Pennsylvania 17108-1933

Telephone (717) 236-7999
Facsimile (717) 232-6608

2525 Blueberry Road, Suite 208
Anchorage, Alaska 99508
Telephone (907) 278-5200
Facsimile (907) 279-2321

520 Second Street
P.O. Box 1829
Cordova, Alaska 99578

Telephone (907) 424-7410
Facsimile (907) 424-7454

April 11, 1991

Honorable H. Russell Holland
United States District Judge
U.S. Courthouse
Anchorage, Alaska 99501

Re: Comments on Criminal Plea Agreement in United States of America v. Exxon Corporation and Exxon Shipping Company, No. A90-015 CR

Dear Judge Holland:

These comments in opposition to the proposed criminal plea and settlement are submitted in behalf of our clients, the Alaska Sport Fishing Association and named individuals who are recreational plaintiffs, the Area Business Class, and approximately 500 other claimants in the civil litigation arising from the Exxon Valdez oil spill. Those plaintiffs represent a variety of recreational, commercial, subsistence and other pursuits involving consumptive and nonconsumptive use of the fish, wildlife, lands and waters affected by the spill. The Association is the largest fishery conservation organization in Alaska and has through political, legislative, administrative, and litigatory efforts achieved conservation of more than a dozen areas, totalling nearly 7 million acres of fish and wildlife habitat in Alaska since the enactment of ANILCA in 1980.

Because the Association and these class and individual plaintiffs are concerned for the conservation of fish and wildlife habitat, and because the monies from this plea and settlement may be used for such purposes, the criminal plea and settlement are of particular concern. The proposed fine is inordinately low, particularly when combined with the inordinately low settlement of civil damages. The manner with which they were reached erodes confidence.

A. This Court Should Not Allow the Governments to Settle Without Encouraging the Governments to Provide an Opportunity for Public Interest Litigants, and Probably Also Private Class Litigants, to Participate in Settlement of Negotiations.

Fundamentally, this is a political case that goes to the heart of how our judicial, executive, and legislative branches of government, as well as our corporate institutions, deal with environmental injuries of great magnitude that affect natural resources and the public in innumerable and complex ways. Here, the executive branch has chosen to operate and settle in isolation, without any opportunity for public interest litigants and private interest litigants to participate.

In a case of this nature, where the science, injuries and damages involve complex relationships between public and private claims, that should not be encouraged. It erodes confidence in the settlement, our corporate institutions and government in general. The importance of such confidence reaches far beyond this spill. By allowing public comment, this court has commendably sought to allow the public to be heard. But informed comment has been thwarted by the long silence on science and the continued silence on damage calculations. That history of silence, isolation and the need for confidence warrants rejection of this settlement. That is essentially the point reached by Congressman George Miller, when he concludes that without

Honorable H. Russell Holland

Page 2

confidence in the Department of Justice, "how is it that Congress and the people . . . can rely on (governmental or corporate) assurances in the future?"

B. This Court Should Apply the Alternative Fines Act, 18 USC Section 3571(d).

In imposing sentence, this court should apply the Alternative Fines Act for purposes of determining the appropriate criminal penalty. The Act provides that the court may impose up to twice the pecuniary loss resulting from the offense. In this case, the defendants have already paid out approximately \$300 million in damages for pecuniary losses occurring in just 1989 and for the most part to just the commercial fishing industry. There are as yet outstanding in excess of \$56 billion in claims filed against the TAPS Fund, much of which is for pecuniary loss. This court should not hesitate to conclude that the pecuniary losses resulting from this spill vastly exceed the \$300 million already paid out.

Therefore, this court is faced with the problem determining an appropriate fine based on only partially determined pecuniary losses. These plaintiffs urge this court to impose a fine as follows: \$600 million (for twice the pecuniary losses already determined) plus \$400 million (not twice, but to address pecuniary losses yet to be determined) with a remittance of any portion of the latter that is not determined.

C. The Court Should Not Accept the Plea Agreement Until the Court Has Received a Summary of the Damage Calculation Studies, and Acceptance of the Plea Agreement Should Be Contingent Upon Scientific and Economic Studies Being Made Public and Being Continued.

It has been impractical for the public, this court, or state and federal officials and legislators to evaluate this settlement or the criminal plea without scientific and economic data being available. While the recent federal release of scientific information shows the injuries to be long lasting and worse than Exxon claims, more importantly, the release shows that the entire ecosystem has been attacked from the lowest to the highest trophic levels.

The signs of this are: (1) the decline in species diversity, abundance and recruitment of benthic organisms that are important to predator-prey relationships and the food chain, (2) the widespread loss of kelp, which has been conservatively documented in similar Alaskan ecosystems to provide 58.3 percent of the organic carbon load into the environment (see Attachment A), and (3) the widespread incidence across many higher trophic species of continuing lethal and sublethal effects such as lost reproductivity, debilitating lesions, mutagenic effects, MFO induction (multi-function oxidases which attack testosterone and estrogen), behavioral and territorial disruptions, low body weight, and decreased growth rates. In general, these are the types of (post-initial mortality) injuries to be expected at higher trophic levels when the lower trophic levels are severely disrupted by oil spill contaminants. Furthermore, these injuries are most prevalent among organisms that more often than not have non-market (and often nonconsumptive) use and intrinsic value, such as marine birds, harlequin ducks, eagles, sea otters, dolly varden, killer whales, harbor seals, and intertidal benthic life, as well as among marketed and non-marketed harvested species such as salmon and shellfish.

Of greater importance are the damage calculation studies. Neither the state or federal governments has released the studies that measure the value of market and non-market losses, including commercial, subsistence, recreational, and intrinsic losses. Various reports in the press, based on interviews with economic experts, have placed the natural resources damages at multiple billions of dollars. A range of \$3 - 10 billion has been mentioned in several recent reports as

Honorable H. Russell Holland
Page 3

coming from economic studies conducted by the State of Alaska that were designed to measure the non-use and intrinsic values associated with the injured natural resources.

To reach a reasonable decision on this settlement, this court needs those studies, particularly the intrinsic value study, every bit as much as it needs the scientific summary. To obtain a summary of the intrinsic value damage study, this court should subpoena the testimony and any summaries prepared by the following experts who, by information and belief, were retained as expert witnesses by the Alaska Department of Law and performed the intrinsic value study: Dr. Richard Carson, Associate Professor of Economics, University of California, San Diego; Dr. Robert Mitchell, Professor of Sociology, Clark University, Worcester MA; Dr. Michael Hanemann, Associate Professor of Agricultural & Resource Economics, University of California, Berkeley; and Dr. Raymond Kopp, Director, Quality of the Environment Division, Resources for the Future, Inc. Washington, D.C. In addition, this court should subpoena Dr. Norman Meade, Chief Economist in the NOAA Damage Assessment Branch, Rockville, MD, who managed the federal studies of recreation damages and intrinsic values, and the following experts who, by information and belief, were retained as expert witnesses by the U.S. Department of Justice to perform those studies: Dr. Alan Randall, Professor of Agricultural Economics, The Ohio State University, Columbus; Dr. John Hoehn, Assistant Professor of Agricultural Economics, Michigan State University, East Lansing; and Drs. Nancy Bockstael, Kenneth McConnell and Ivar Strand, Professors of Agricultural & Resource Economics at the University of Maryland, College Park.

The federal and state studies of intrinsic value employed the contingent valuation approach that was recently upheld by the U.S. Court of Appeals for the District of Columbia Circuit. By information and belief, these studies had been under way for a period of about eighteen months at the time the settlement was submitted to this court and they had reached preliminary conclusions indicating a range of \$3 - 10 billion for the non-use component of the natural resources damages. The range arises from the fact that, by design, the studies sought only a lower bound on the damages and reflects differences due to the use of willingness to pay versus willingness to accept, differences in the payment vehicle and the period of time over which payments would be made, and -- most importantly -- differences in the extent and duration of the natural resources injuries. In the light of the scientific information concerning these injuries that has just been released by the federal government, it is more than likely that a final analysis of the contingent valuation data will place the value of the non-use damages near the high end of the \$3 - 10 billion range.

We urge this court not to accept this settlement and plea agreement until such information is before it and that any acceptance be contingent on release and continued assessment of damages for loss of commercial, subsistence and recreational use of natural resources, as required by 43 C.F.R. 11.83. By information and belief, including statements of Attorney General Cole at the April 6 legislative hearing, we believe those studies are not complete and that the governments have effectively turned their backs on their citizens.

D. The Settlement Represents a Gross Violation of the State and Federal Governments' Fiduciary Obligations as Trustees for the Natural Resources Injured by the Oil Spill.

From numerous press accounts of the settlement, it is abundantly clear that it was a political decision on the part of a few key players in the state and federal governments who bypassed the entire natural resource damage assessment process. By information and belief, the amount of the settlement was in no way grounded in the information developed by the scientists and economists working on the damage assessment. The idea of settling for around one billion dollars originated with Governor Hickel a few weeks after the election, if not earlier -- well before he had taken office or had obtained access to the information developed by the damage assessment.

Honorable H. Russell Holland

Page 4

At the federal level, the settlement was promoted by Secretary of Transportation Skinner, who is not a trustee and who, by his own account, was not conversant with the findings of the damage assessment.

The final agreement calls for payment of \$900 million for natural resource damages over a period of more than 10 years without interest. The trustees' decision to forego interest on the natural resource damages violates the decision of the DC Circuit Court of Appeals upholding payment of interest at a rate of 10%, and reduces the costs of conducting the damage assessment and the costs of restoration, which would be fully recoverable with interest accruing from the time that they were incurred. When these costs are subtracted from the amount of the settlement and the remainder is converted to present value terms, recognizing the time value of money, the settlement for loss of use value, non-use value, option value, amenity value, bequest value, existence value, consumer surplus, economic rent and related natural resource values amounts, at best, to about \$450 million.

By information and belief, this trifling sum is grotesquely out of proportion to any reasonable estimate of these damages and bears no relation whatsoever to the information developed by the state and federal damage assessment teams. Indeed, the trustees would have reached a figure considerably larger than \$450 million if they had merely taken the estimated kill of fish and wildlife immediately after the spill and multiplied this by replacement cost figures that have been used in earlier cases to value a very limited set of natural resources damages.

For example, in the case of the T/V Puerto Rican oil spill off the coast of San Francisco in 1984, NOAA published a damage assessment report in 1986 valuing the birds killed in the incident at from \$575,000 to \$1,528,000 using the replacement cost method, based on estimates from zoological institutions and supply houses of what it would cost to obtain replacement specimens of the birds affected. (See Attachment B.) This case was subsequently settled for about \$750,000. The Exxon Valdez spill involves many of the same species of birds. NOAA's estimate of the replacement cost for these birds was from \$200 to \$500 per bird at 1986 prices. When these replacement costs are applied to the estimates of bird losses just released by the federal government for the Exxon Valdez spill, and when similar replacement costs are applied to the many other wildlife and fish losses and the injuries to land, it is evident that a damage estimate of well over \$1 billion would be obtained for just initial effects.

It is widely recognized, including by the NOAA Attachment, that estimates of replacement cost from supply houses significantly understate the true cost of replacing of wildlife, quite possibly by an order of magnitude because it is impossible to buy a half million wild birds, let alone other wildlife. Furthermore, because of delays before restoration can be effected, there are additional, interim, losses to the fish and wildlife populations that would have to be added to this \$1 billion of damages. One would also have to add the loss of recreation and other use values. The resulting total damage would be compounded at 10% interest from the time the damage occurred until the time that payment was received by the trustees. All of this is added to the state and federal governments' other expenses for damage assessments, cleanup and restoration that are fully recoverable under existing law.

By settling for an amount that is so much lower in present value terms, and by failing to provide a credible explanation of the settlement or to relate it in a meaningful way to any theory of damage valuation, the trustees have cast aside their fiduciary obligations to determine the magnitude of natural resources damages and account for them to the general public. If this court does not intervene, it will send a signal that such wanton misconduct by trustees can become the norm in all future natural resource damages cases.

Honorable H. Russell Holland
Page 5

Furthermore, the gross imbalance between the actual settlement of \$450 million for natural resource damages and any reasonable accounting of such damages makes a mockery of the re-opener clause. Under this clause, an amount no more than \$100 million is payable in 2002 for injuries that could not reasonably have been known at the present time. According to press reports, William Reilly, the Administrator of the EPA had recommended that \$300 million be set aside for this purpose. When viewed as a proportion of the likely natural resource damages that already are known to the trustees --if they choose to consult their damage assessment -- even this amount seems small. By failing to provide any rationale for capping the re-opener at \$100 million, the trustees have violated their fiduciary obligations and set a bad precedent for future natural resource damages cases.

E. This Court Should Strike the Prohibition on Judicial and Administrative Review in Paragraph IV B.

Paragraph IV B provides that the State of Alaska may spend monies from the criminal plea without public objection, challenge, or judicial or administrative review. This prohibition is unconscionable. It allows the State of Alaska to spend in any manner whatsoever and should be stricken from the agreement.

F. Alyeska Should Not be Excused From Criminal Liability.

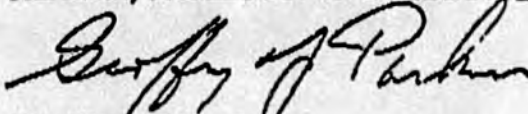
Congressman Miller has described Alyeska's broken promises regarding its ability to prevent or respond to a spill of this magnitude. The merits of any criminal case or civil penalties against Alyeska cannot be determined without court proceedings, but to foreclose that possibility erodes confidence that government diligently prosecutes major corporate perpetrators of environmental crimes. The exculpation of Alyeska should be stricken.

CONCLUSION

The political nature of this highly public case demands that the court scrutinize carefully the secretive process and evidence behind this settlement. Private litigants, particularly public interest litigants, should not have been foreclosed from that process. This court can redress that process by rejecting this criminal settlement and effectively urging the governments to pursue a more open settlement of civil aspects of this case brought by both governments and numerous public interest and class litigants. By so doing, this court will be sensitive to its own vital role in sustaining public confidence in public institutions.

Respectfully submitted,

ADLER, JAMESON & CLARAVAL


Geoffrey Y. Parker

Resource Damage Assessment of the T/V Puerto Rican Oil Spill Incident

April, 1986

Prepared for:

United States Department of Commerce
National Oceanic and Atmospheric Administration
National Ocean Service
Office of Ocean and Coastal Resource Management
Sanctuary Programs Division
Washington, D.C. 20235

Under Contract Number
50-DGNC-6-00102

Prepared by:

James Dobbin Associates Incorporated
Coastal and Ocean Planners
110 North Royal Street, Suite 300
Alexandria, VA 22314



Attachment B

commercial fishery of the area depends. Thus, not only would many of the larvae have been valuable in themselves if they had lived to become adults, but the entire commercial fishery would have been more productive. Unfortunately, current ecological theory will not support an estimate of the total injury done to the commercial fishery as a result of the destruction of a part of the food chain upon which it depends.

Replacement Costs

222 A replacement cost approach can avoid many of the problems involved in attempting to estimate the use value of biological resources. Under the replacement cost approach the resource is valued at what it would cost to replace it. If the resource is replaced, the problems of identifying all its uses, the monetary value of these uses, and the users affected by the resource loss are eliminated, except for the period between the initial loss and the replacement.

223 Twenty-three institutions were asked to estimate the cost of obtaining specimens of the birds killed in the Puerto Rican oil spill, or the price at which they would be willing to sell members of each species (Sterling Hobe Corporation 1985; and California Department of Fish and Game 1985). Nine institutions responded and their estimates are shown in Figure 23.

224 One problem with most of these estimates is that they are not true replacement costs, but rather the cost of collecting already existing specimens from the wild and redistributing them to the Gulf of the Farallones area. This does not represent true replacement, since true replacement requires a complete recovery of the species population. This can be most clearly assured by using only captive breeding programs for replacement.

FIGURE 23

ESTIMATES OF SEABIRD SPECIES VALUE/PRICE FROM VARIOUS SOURCES

(In dollars per one specimen)

SPECIES	SOURCE								
	Seattle Aquarium	Sea World	Los Angeles Zoo	Myrtle Marine Life Aquarium	New York Zoological Park	Busch Gardens	International Zoological Distributors	International Animal Exchange	Boston Zoological Gardens
Common Loon		200	140		1500		200	300	250
Arctic Loon		180	300		1500		300	300	250
Red-throated Loon		280	500		2500		300	300	250
Loon spp.		200			1500			300	250
Western Grebe	75	200	250		1800		25	300	250
Red-necked Grebe	75	200	300		1800		25	300	250
Horned Grebe	75	200	300		1800		25	300	250
Hared Grebe	75	200	250		1800			300	250
Grebe spp.					2000			300	250
Northern Fulmar					500			300	250
Sooty Shearwater		100	200		500			300	250
Deandt's Cormorant			75	200		500		300	250
Pelagic Cormorant			200		500			300	250
Cormorant spp.		75	280		500			300	250
Northern Pinnell	20			50	200	35	15	300	250
Ruddy Duck	150	75		30	300	75	20	300	250
Greater Scaup		37	150		200	50	15	300	250
Scaup spp.			150		200			300	250
Black Scoter					500		150	300	250
Surf Scoter	220	1000	700		500		150	300	250
White-winged Scoter	220	1000	300		500		250	350	300
Scoter spp.					500			300	250
American Coot			50		300		10	300	250
Red Phalarope		50	100		150			300	250
Western Gull			50		50			300	250
Common Murre	220	100	200		500			300	250
Pigeon Guillemot	220	100	250		500			300	250
Cassin's Auklet	220	100	250		500			300	250
Mottled Murrelet	220	100	250		500			300	250
Rhinoceros Auklet	220	100	200		500			250	200
Ancient Murrelet									
Auklet spp.		100	200		500			300	250
Red-tailed Hawk	50				500		150	300	250

Sources: Sterling Noble Corporation 1985

PER-12-91 PER-12-03 BLEDSOE & KNUTSON

However, most of the species in this list are not and probably cannot be bred in captivity (Briggs, pers. comm.). Therefore, true replacement from captive breeding is probably impossible. It is absurd to value them at 0 since they cannot be replaced. Therefore, this section presents some calculations on the assumption that they could be redistributed or replaced.

225

Figure 24 presents a range of calculations, multiplying the number of dead birds times the second lowest and the second highest replacement costs given in Figure 23. The second lowest and highest costs were selected in order to eliminate extreme values. Using this approach, the total replacement costs for the birds estimated to have been killed in the Puerto Rican incident amount from \$574,692 to \$1,528,050.

226

An alternative approach to estimating replacement costs is to estimate the cost of creating new habitat or enhancing existing habitat to support enough nesting pairs of each species to replenish the population. Again, to represent true replacement costs, this should be new or enhanced habitat, not just the cost of acquiring already existing habitat. Research on estimating replacement costs based on this alternative approach is currently being conducted and will be concluded within the next several months. Upon completion of this research, the estimates of habitat replacement or enhancement will be included in a supplement to this report.

227

If replacement of the birds were attempted, it would take several years to accomplish. In the interim, there would be a loss of use which would have to be included to derive the total cost of a replacement strategy. Most of the birds destroyed in the Puerto Rican incident require three to twelve years to mature. Assuming no natural regeneration and that the replacement effort began immediately after the spill and all the replacement birds were released three years later, there would be three years lost use in addition to the

FIGURE 14**REPLACEMENT COST FOR MARINE BIRDS**

SPECIES	TOTAL DEAD BIRDS *	LOW ESTIMATE		HIGH ESTIMATE	
		Cost/Bird	Total Cost	Cost/Bird	Total Cost
Common Loon	19	200	3,800	800	15,200
Arctic Loon	176	250	44,000	800	140,800
Red-throated Loon	6	250	1,500	800	4,800
Loon spp.	-	-	-	-	-
Western Grebe	109	75	8,175	800	87,200
Red-necked Grebe	2	75	150	800	1,600
Horned Grebe	7	75	525	800	5,600
Eared Grebe	25	200	5,000	800	20,000
Grebe spp.	1	75	75	800	800
Northern Fulmar	-	500	-	500	-
Sooty Shearwater	3	200	600	500	1,500
Brandt's Cormorant	2	200	400	500	1,000
Pelagic Cormorant	3	150	450	500	1,500
Cormorant spp.	2	150	300	500	1,000
Northern Pintail	1	20	20	200	200
Ruddy Duck	5	75	375	300	1,500
Greater Scaup	2	37	74	150	300
Scaup spp.	-	-	-	-	-
Black Scoter	-	250	-	500	-
Surf Scoter	25	228	5,700	800	20,000
White-winged Scoter	10	228	2,280	800	8,000
Scoter spp.	-	-	-	-	-
American Coot	13	30	390	300	3,900
Red Phalarope	10	100	1,000	150	1,500
Western Gull	33	50	1,650	50	1,650
Common Murre	1856	200	371,200	500	928,000
Pigeon Guillemot	2	228	456	500	1,000
Cassin's Auklet	548	228	124,944	500	274,000
Marbled Murrelet	1	228	228	500	500
Rhinoceros Auklet	4	200	800	500	2,000
Ancient Murrelet	1	200	200	500	500
Alcid spp.	7	200	1,400	500	3,500
Red-tailed Hawk	1	100	100	500	500
TOTALS	2874		\$575,792		1,528,050

* November 20, 1984 to May 30, 1985

to 32%, K_2O = 5 to 9%, and CO_2 = 27 to 32% (3-5, 15). Analyses of fresh samples, which were sealed before complete cooling, indicate that the 1988 lavas were almost water-free. The volatile contents of F (2.5 to 4.5%), Cl (3.5 to 5%), and SO_2 (4 to 5.5%) are higher than reported previously for the 1960 lavas (15). Such high volatile concentrations no doubt contributed to the lower solidus temperature of the lava of Oldoinyo Lengai compared with that of the synthetic system studied by Cooper *et al.* (13).

The temperature measurements on natural lava flows are in good agreement with experimental melting-temperature determinations carried out on samples from the same flows. The rock powder of the natural lava melted easily at temperatures of 500° to 550°C. The melting temperature at 1 atm was determined by differential thermal analysis (DTA) and differential thermal gravimetry (DTG). A pronounced DTA endotherm, representing the onset of melting, began at 490°C (±5°) and had its maximum at 510° to 520°C. This range (490° to 520°C) is similar to the range of the temperature measurements of the lava flows. Dissociation of CO_2 from the carbonate melt began at 660°C.

The observed temperatures are several hundred degrees lower than the lowest 1-atm temperatures of silicate lavas. Significant cooling must have occurred from temperatures of possible partial melting in the mantle (6). Concomitant crystallization can account for the distinctly fractionated composition of nanocarbonates (5, 6, 15).

REFERENCES AND NOTES

1. H. Bask and G. Schultz, *Earth. Planet. Sci. Lett.* 6, 47 (1971).
2. J. B. Dawson, in *Carbonates*, O. F. Tuttle and J. G. Thompson, Eds. (Interscience, New York, 1966), pp. 155-168.
3. *Nature* 198, 1075 (1963).
4. C. G. Du Bois *et al.*, *ibid.* 197, 445 (1963).
5. J. G. Thompson and D. McKie, *Lithos* 13, 215 (1980); J. D. Twyman and J. G. Thompson, in *Alkaline Igneous Rocks*, J. G. Thompson and B. G. J. Upton, Eds. (Spec. Publ. 30, The Geological Society, London, 1987), pp. 85-94.
6. M. E. Wallace and D. H. Green, *Nature* 335, 343 (1988).
7. J. Keller, L. Crisp, and R. H. S. Yoder, Jr., *Earth. Planet. Sci. Lett.* 44, 70-82 (1979).
8. T. Davis and B. Roberts, *J. Geol. Soc. London* 141, 565 (1984); M. J. Le Bas, in *Alkaline Igneous Rocks*, J. G. Thompson and B. G. J. Upton, Eds. (Spec. Publ. 30, The Geological Society, London, 1987), pp. 83-84.
9. J. B. Dawson, P. Bowden, G. C. Clark, *Geol. Resour.* 57, 868 (1968).
10. C. Nyman, *J. Afr. Earth Sci.* 7, 603 (1988).
11. J. J. Richard, *J. East Afr. Uganda Nat. Hist. Soc.* 16, 89 (1942).
12. H. J. Gacit, *Geol. Surv. Tanganyika Rep.* 4, 54 (1968).
13. A. P. Cooper *et al.*, *Am. J. Sci.* 278, 534 (1978).
14. All temperatures were taken with OmegaCorp thermocouples chromel-alumel NiCr-NiAl; range -85° to +777°C. Consistency was checked with two instruments.

15. J. Keller and M. Kraft, *TERRA* 2, 286 (1989).
16. During November 1988, B. Dawson and co-workers (B. Dawson, personal communication) carried out additional temperature measurements and obtained higher temperatures from 573° to 597°C. These data show that better magma is available at depth.
17. The DTA and DTG analyses were carried out at the

Kenneth G. Bledsoe, University of Washington, Seattle, WA 98195. V. Kramer is thanked for his help. The members of the expedition, K. Kraft, C. Wern, C. Hug-Pick, and A. Domanov are thanked. We also thank the Peterson family, Arusha, and our local porters for their help.

27 February 1989; accepted 26 April 1989

Magnification of Secondary Production by Kelp Detritus in Coastal Marine Ecosystems

D. O. DUGGINS, C. A. SIMENSTAD, J. A. ESTES

Kelps are highly productive seaweeds found along most temperate latitude coastlines but the fate and importance of kelp production to nearshore ecosystems are largely unknown. The trophic role of kelp-derived carbon in a wide range of marine organisms was assessed by a natural experiment. Growth rates of benthic suspension feeders were greatly increased in the presence of organic detritus (particulate and dissolved) originating from large benthic seaweeds (kelps). Stable carbon isotope analysis confirmed that kelp-derived carbon is found throughout the nearshore food web.

ALTHOUGH PHYTOPLANKTON IS undoubtedly the primary source of organic carbon in much of the world's oceans, benthic plants are thought to be important contributors to food webs in estuarine and coral reef habitats (1). In the early 1970s, Mann and others (2-4) showed exceptionally high productivity in benthic macrophytes belonging to the order Laminariales (kelps) and inferred that kelp-derived organic carbon could play a significant role in temperate coastal (nearshore) secondary production. We assessed the significance of kelp-derived organic carbon to secondary production by a natural experiment involving islands in the Aleutian archipelago (Alaska) with and without sea urchins, and thus with and without extensive kelp forests (5). We show that growth rates of benthic suspension feeders are two to five times as high at kelp-dominated islands as at those without kelp beds. Stable carbon isotope ($\delta^{13}C$) analyses show that kelp-derived carbon contributes significantly to the carbon assimilated by secondary consumers at these islands.

Kelps are a dominant feature of many exposed and semilexposed temperate coastlines, where they frequently form dense stands from the low intertidal zone to depths approaching 40 m. Individual kelps can achieve large biomass and rapid growth even at high density, thus forming one of the world's most productive habitats (3, 6). Benthic marine herbivores such as sea urchins (Echinoidea) can retard the growth of kelp populations and occasionally decimate kelp populations, but most kelp biomass is not consumed directly (7). This has led to

speculation that kelp biomass enters the nearshore food web through indirect (vertical) routes. By releasing particulate as well as dissolved organic matter (POM and DOM respectively) as they grow and senesce, kelps could provide a significant organic carbon source for the diverse and abundant assemblages of nearshore suspension feeders, benthic as well as benthic. Even the considerable quantity of kelp biomass deposited on beaches adjacent to kelp stands ultimately may reenter the nearshore food web as POM and DOM after decomposition.

The reestablishment of sea urchins in the Aleutians after their near extinction in the 19th century and the subsequent resurgence of other predation upon sea urchins allow us to compare secondary production between areas that differ greatly in kelp biomass but are otherwise similar. Oceanographic data indicate that the pervasive influence of the westward-flowing Alaskan Stream accounts for relatively uniform physical conditions among the central and western Aleutian Islands (8). Neither the few prior studies nor our surveys provide evidence for significant differences in species composition (including phytoplankton) along this segment of the archipelago (9).

The mid- and low-intertidal zones throughout the Aleutian Islands are dominated by kelps belonging to the genus

D. O. Duggins, Friday Harbor Laboratories, Friday Harbor, WA 98250.
C. A. Simenstad, Fisheries Research Institute, WSU, University of Washington, Seattle, WA 98195.
J. A. Estes, U.S. Fish and Wildlife Service, Institute of Marine Sciences, University of California, Santa Cruz, CA 95064.

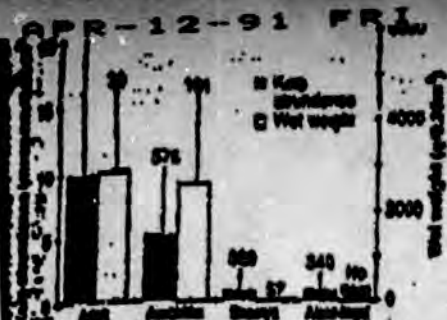


Fig. 1. Kelp abundance and wet weight (mean and 1 SD) of quadrat counts and sample weights for four islands with sea otters (Adak and Amchitka) and without otters (Shemya and Aleid-Nikolai). Sample size is given above each error bar.

Laminaria and *Aleria*, which exist in a refuge above the foraging range of sea urchins. Rocky subtidal habitats at islands with sea otters are characterized by low urchin biomass and large stands of both understory and surface canopy kelps; however, islands where sea otters have not become reestablished are characterized by large urchin biomass and few kelps (5). This nearshore community variation allowed us to assess (by comparison) the importance of kelp input to the production of nearshore consumers. Between 1985 and 1987 we conducted benthic surveys, experiments, and analyses at Adak and Amchitka Islands (otter abundant) and at Shemya and Aleid-Nikolai Islands (no sea otters) to determine whether growth (as an indicator of production) and $\delta^{13}\text{C}$ of consumer organisms were related, positively to kelp bio-

mass. Benthic surveys verified differences in kelp abundance and biomass between islands. At each island, transects were established at 16 to 80 randomly selected sites along the 6-m contour. All sites were judged subjectively to be of similar exposure. Along each transect, 20 randomly selected 0.25-m² quadrats were censused by divers for kelp abundance. The kelp data (Fig. 1) show orders of magnitude differences in subtidal kelp abundance and biomass between islands with and without sea otters. Although abundance and biomass are not synonymous with production, research on similar kelp assemblages has shown that benthic production should be different among these islands (2, 10). Kelp-derived organic carbon is available to nearshore suspension feeders, detritivores, and (indirectly) their predators, and if kelp alone is a limiting resource, then secondary production should be very different between islands. We used two analyses to determine if suspension-feeding organisms

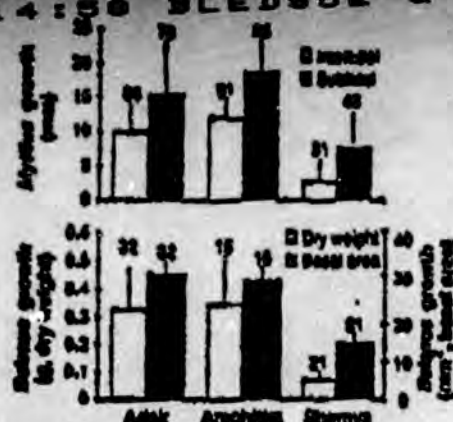


Fig. 2. Results of translocation experiments; means and 1 SD of growth in length (mussels, *Mytilus*) or dry weight and basal area (barnacles, *Balanus*). Sample size is given above each error bar.

grow faster in kelp-dominated than in urchin-dominated environments. First, we translocated two species of suspension feeders (the mussel *Mytilus edulis* and the barnacle *Balanus glandula*) from a common source (Puget Sound, Washington) into cages at six intertidal and six subtidal sites at Adak, Amchitka, and Shemya Islands. Mussels were translocated in 1985 and 1986 and barnacles in 1986. Mussels were individually tagged and measured (maximum valve length) (12); barnacles were allowed to settle on fiberglass plates, thinned to minimize competition, and measured in four dimensions (length and width of operculum and base). Barnacle locations were mapped for individual identification and the plates were placed in the same cages with the mussels. All animals were remeasured after 1 year. Mussel valve elongation, barnacle final dry weight (15), and change in barnacle basal plate area were the parameters used to compare growth among islands.

Growth rates were significantly different (14) among islands. Mussels in kelp-dominated habitats (Adak and Amchitka) grew approximately two (subtidal) to four (intertidal) times as fast as mussels in urchin-dominated habitats (Fig. 2). Likewise, barnacles (intertidal) grew up to five times as

fast in kelp-dominated environments (Fig. 2) (barnacles from subtidal cages did not survive).

As a second, independent verification of the translocation data, age-size relations were analyzed for intertidal mussels collected from six sites at each of four islands (15). Mussel valves were sectioned and age determined by the methods of Lutz (16). For year classes 2 to 5, mussels were significantly larger at islands with substantial subtidal kelp forests (Fig. 3) (17).

Our results do not exclude the possibility that a carbon source other than that derived from kelps accounted for differences in mussel and barnacle growth among islands. We employed $\delta^{13}\text{C}$ analyses to determine the extent to which consumers were using kelp-derived organic carbon and if such use differed among islands as predicted (18). The Aleutian nearshore food web lends itself well to such analyses for several reasons. Unlike other habitats such as estuaries where diverse autotrophs (phytoplankton, benthic algae, and marine and terrestrial angiosperms), each with a distinctive $\delta^{13}\text{C}$ signature, contribute POM and DOM to nearshore waters, the Aleutians have only two principal sources of organic carbon: benthic algae and phytoplankton (19). Furthermore, at high latitudes, phytoplankton is more depleted in ^{13}C than at low latitudes (20) and thus the difference in signatures between kelps and phytoplankton is large, leading to less ambiguous interpretation of the origins of organic carbon in nearshore consumers. In addition, because islands differ greatly in the potential input of kelp carbon, we could incorporate the measured consumer $\delta^{13}\text{C}$ enrichment in kelp-dominated islands in a simple mixing model to assess quantitatively the magnitude of kelp carbon input to the nearshore food web.

To characterize predominant carbon sources, $\delta^{13}\text{C}$ was determined from samples of the dominant kelps (*Laminaria groenlandica*, *L. longipes*, and *Aleria fistulosa*) collected at Adak and Amchitka Islands. Six suspension feeders, two detritivores, and three

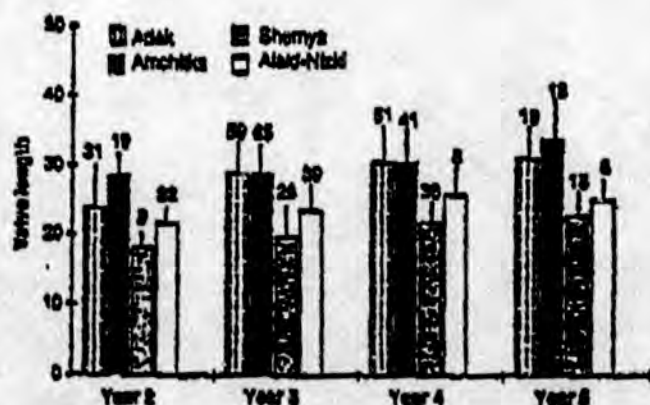


Fig. 3. Age-size relations for *Mytilus edulis* at four Aleutian Islands; means and 1 SD of valve length. Sample size is given above each error bar.

predator taxa were collected at each island as indicators of the islands' nearshore consumers (21). Phytoplankton isotopic values were derived from cultures incubated on board the R.V. *Alpha Helix*. Cultures inoculated from ambient seawater were used rather than net tow samples because of the inevitable problem of contamination by non-phytoplankton carbon in plankton net tows. These cultures were made up primarily of *Chlorella* and *Thalassiosira*, which were the dominant genera in net tows at all islands as well as the most common genera reported for the region (9). The mean phytoplankton isotopic value (-24.0 per mil ± 1.0 SD, $n = 5$) corresponds with published values (-22.9 to -24.4 per mil) for this region and surface water temperatures. Kelps were considerably enriched in ^{13}C relative to phytoplankton, and values were relatively consistent among taxa and islands (overall mean of -17.7 per mil ± 2.3 SD, $n = 162$).

Differences in consumer $\delta^{13}\text{C}$ between kelp-dominated islands and urchin-dominated islands support the hypothesis that carbon fixed by kelp is found throughout the nearshore food web and may even be consequential at islands with comparatively low kelp abundance. For each of 11 consumers tested, with the single exception of *Mytilus edulis* (22), mean $\delta^{13}\text{C}$ values for animals from kelp-dominated islands (Adak and Amchitka pooled) were more enriched than mean values for animals from islands without kelps (Sitka and Alaid-Nizid pooled).

(23). On the basis of a simple mixing model (24), primary consumers at kelp-dominated islands average, conservatively, 58.8% kelp-derived carbon (Fig. 4), whereas at urchin-dominated islands they average only 32.0%. This was the case despite all consumers being collected in midsummer during periods of peak phytoplankton abundance, when $\delta^{13}\text{C}$ values should be indicative of maximum phytoplankton influence. The moderate percentage of kelp-derived carbon in consumers at urchin-dominated islands is probably the result of input from intertidal kelps and kelps existing in subtidal refuges from urchin grazing. The relatively consistent enrichment of consumers at Adak and Amchitka, regardless of feeding type or trophic level, argues for the pervasive occurrence throughout the nearshore food web of organic carbon originally derived from kelp photosynthesis.

Both the transplant translocation experiments and age-size analysis show that suspension feeders grow at a significantly higher rate at islands with extensive subtidal kelp forests than at those without. The $\delta^{13}\text{C}$ data indicate that this difference in growth rate most likely results from the use of organic carbon photosynthesized by kelps, rather than from differences among islands in phytoplankton production or some other variable. Isotopically enriched signatures of organisms such as mussels, rock greenling, and pelagic cormorants at kelp-dominated islands further indicate that use of kelp-de-

rived organic carbon is not restricted to benthic organisms.

The ecological role of kelps in the short region is multifaceted. Strong evidence exists that they provide habitat (stratum and canopy) for a wide range of benthic, epibenthic, and pelagic organisms and alter the hydrodynamic environment of the nearshore region (25). Here we report a strong trophic link between kelps and a range of organisms of varied feeding ecology and trophic levels, extending beyond the obvious kelp-grazer-predator chain. The common occurrence of extremely highly productive kelp forests along a temperate to subpolar coastline suggests that our results are not specific to the Aleutian Islands. The relative trophic contributions of kelp detritus and phytoplankton may vary with latitude, habitat, or season, particularly given the punctuated nature of phytoplankton production. The role of kelp production may actually be greatest in winter, when phytoplankton production is at a minimum, and kelp standing stock is old and senescing (annual species) or being physically degraded during storms (annual and perennial species).

Our data support quantitatively the suggestions of Mann (2, 5) and others that kelps contribute significantly to coastal secondary production, perhaps ultimately establishing limits to the abundances of food-limited populations. Factors affecting kelp occurrence and production such as the recolonization or extinction of sea otters, sea urchin disease, catastrophic storms, nutrient depletion during El Niño events, or oil spills and other pollution are thus likely to have wide ranging and often long-lasting influences on the productivity of coastal ecosystems.

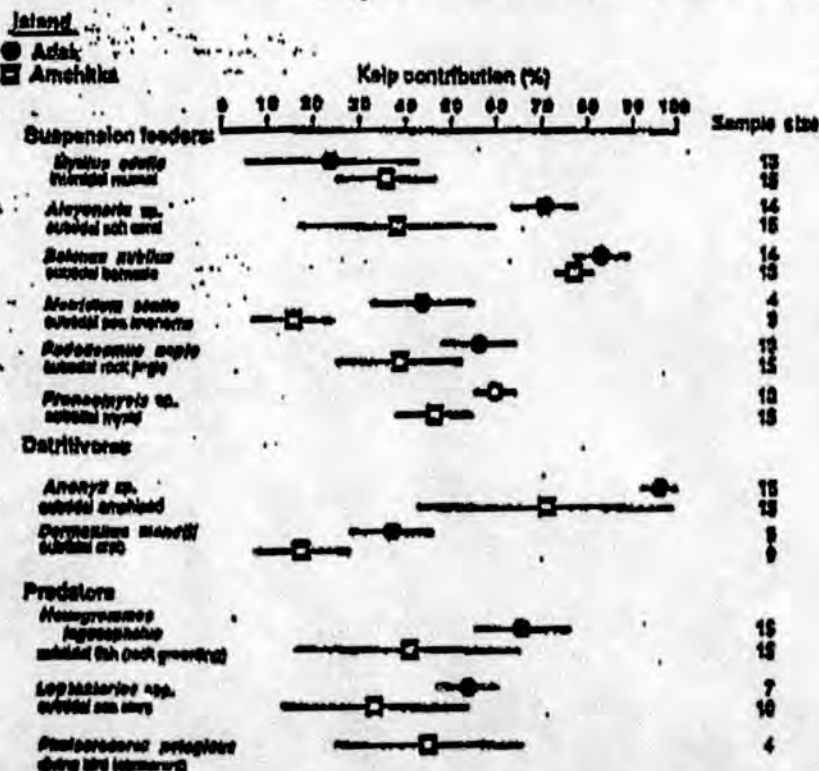


Fig. 4. Percentage of carbon photosynthesized by kelps found in tissues of consumers at islands with extensive subtidal kelp beds. Values are means and ± 1 SD. Three to five samples were collected and analyzed from each of three sites at each island.

REFERENCES AND NOTES

1. R. C. Newell, in *Flow of Energy and Matter in Marine Ecosystems*, M. J. R. Fasham, Ed. (Plenum Press, New York, 1984), pp. 317-343; C. A. Stoeck and R. C. Newell, *Mar. Ecol. Prog. Ser.* 22, 161 (1985); R. C. Newell, *Mar. Ecol. Prog. Ser.* 22, 161 (1985).
2. K. H. Mann, *Mar. Biol.* 14, 199 (1972).
3. ———, *Science* 182, 775 (1973).
4. D. O. Duggins, *Ecology* 61, 447 (1980).
5. J. A. Evers and J. F. Pedersen, *Science* 186, 1022 (1974); J. A. Evers et al., *Ecology* 69, 823 (1979).
6. K. H. Mann, *Ecology of Coastal Waters: A Special Approach* (Univ. of California Press, Berkeley, 1982).
7. C. Harold and J. E. Pomeroy, in *Estuarine Studies*, J. Hargrave and J. M. Lawrence, Eds. (Baltimore, 1987), pp. 187-223; V. A. Garritt, *Univ. of California, Santa Cruz* (1976).
8. F. Forrester, *Cons. Publ. Int. Mar. Sci. Univ. Alaska* (1974), pp. 3-37; W. R. McAllister and F. Forrester, in *The Environment of Amchitka Island, Alaska*, M. L. Merritt and R. G. Poff, Eds. (Ecology Research and Development Administration, Oak Ridge, TN, 1977), pp. 331-382.
9. S. Morada and T. Minoda, *Cons. Publ. Int. Mar. Sci. Univ. Alaska* 2 (1974), pp. 207-241; F. A. Lohr and J. F. Pedersen, in *The Environment of*

